CONVAIR F-102

An Analysis of America's Home-defence Intercepter

By THE TECHNICAL EDITOR

FROM many aspects, Convair's history of delta-wing intercepter development is a story of exceptional interest. Much can be learned from an overall survey of how the concept grew and developed, what sort of weapon system has resulted and how it is built and operated. Briefly, the story is that of a futuristic conception, a massive research programme into unknown realms of aerodynamics, gradual translation into an integrated intercepter system, disappointing flight trials, complete redesign to turn an indifferent aeroplane into a very good one and, finally, a programme of development and production which is a text-book model of perfection.

Upon the Convair F-102 devolves a weighty responsibility. Its mission is a cut-and-dried one: to intercept and destroy, under any operational conditions, any enemy aeroplane which might cross the American frontier. These words come readily enough from the pen; yet twelve years ago—when the U.S. Air Force's standard all-weather and night fighters were the piston-engined Black Widow and Twin Mustang—such a specification seemed unattainable. The jet bomber and the nuclear weapon multiplied the problems of nation-wide defence a thousandfold.

Such were the problems posed by the new situation that, even though the keynote of the period was a run-down of military forces, the U.S. Defense Department originated a specification for an intercepter with a performance surpassing that of any previous piloted aeroplane. The requirement resulted in the Convair Company (now a Division of General Dynamics Corporation) receiving an Air Force assignment to develop such an aircraft. The first contract was let before 1945 was out.

Although Convair were even then one of the world's largest aircraft companies they felt justifiably diffident about so great a stride into the unknown. It was a period in which several completely new families of transonic wings were being discussed, without anyone having sufficient practical knowledge to recommend which type should be chosen. Back in the 1930s the N.A.C.A. had conducted a purely theoretical investigation into the characteristics of wings of triangular plan-form. From the end of World War 2 crate-loads of captured German calculations and tunnel data on transonic wing design became available, and a considerable proportion of the latter also suggested a triangular, or "delta", plan-form. The problem was placed in the hands of Convair's Downey plant, with prime responsibility assigned to Adolph Burstein, the assistant chief engineer of the San Diego Division, and Ralph H. Shick, chief of aerodynamic research. These experienced men tentatively decided to recommend a delta wing for the new fighter. Most of the German material on such wings had stemmed from the Lippisch group. Convair tracked down Lippisch at Wright-Patterson A.F.B., and Shick flew there to talk to the man himself.

Shick came back to California convinced that the delta was the right choice, and his assurance injected a new spirit of enthusiasm and confidence within the company. Work went ahead during 1946 on what was then the only delta programme in the world. For little over $150 a rough tunnel model was made, and the results were so impressive that the Air Force accepted the configuration for the future intercepter. Convair built more, and better, models and launched a tunnel programme of previously unparallelled magnitude. Over 5,000 hours were logged before an aeroplane was built.

Finally the design and construction of a full-scale aeroplane began as the Model 7002, with Thomas M. Hemphill of San Diego as project engineer. Time and money were against him and he employed parts of five other aircraft in the design. In 1947 activities at the Downey Division were suspended and the work was transferred to the main plant at San Diego. Late in November of that year the first aircraft (U.S.A.F. serial number 46-682) was mounted for tunnel testing at the N.A.C.A. Ames laboratory, and the subsequent results were described as "exceptional". The Allison J33-A-23 engine was then installed and a long programme of ground testing and high-speed taxying began at Muroc (now Edwards A.F.B.). The machine finally took to the air in the hands of E. D. ("Sam") Shannon, then San Diego chief test pilot, just after dawn on September 18, 1948. As far as is known, this was the first flight of a true delta-wing aeroplane.

Subsequent flight experience extended over several years, and the 7002 was flown by many civilian and military pilots. By 1949 the original F-92 specification for a turbojet/rocket intercepter had been abandoned, but the 7002 was accepted by the Air Force as the XF-92A research vehicle. In 1951 it was back at Edwards for advanced U.S.A.F. testing; it was assigned to the N.A.C.A. the following year, and finally wound up as a U.S.A.F. travelling exhibit.

It served to provide the U.S. Air Force and aircraft industry with a vast quantity of data on delta-wing characteristics up to a Mach number of 0.95. Many designers consider that the delta is ideally a supersonic configuration and, from the outset, Convair adopted a leading-edge sweep of 60 deg and a low thickness/chord ratio, thus making their test results applicable to the design of supersonic aircraft. They found that, although the maximum lift coefficient was not high, and that it could be obtained only at very high angles of attack (a possible source of trouble to the pilot), the wing otherwise performed admirably and seemed to offer the best overall basis upon which a supersonic intercepter design could be planned.

One of the major variables concerned the choice of armament. By 1950, research by the U.S.A.F. had proved the feasibility of the collision-course attack, using folding-fin, spin-stabilized rockets;

but neither the gun nor the air-to-air missile could lightly be discarded. The Air Force were anxious that the supersonic intercepter should employ a guided air-to-air missile and, in view of the long-term nature of the programme, it seemed practicable to design the aircraft simply as a carrying vehicle for such a weapon.

In order to develop a complete integrated weapon system—a concept which was then (1950) beginning to be appreciated—the Air Force first held a design competition for a complete fire-control system (MX1179) for such an intercepter. The purpose of this mass of electronics would be to insure the success of each mission, by putting the aircraft in the right place at the right time, and pointing in the right direction, and then launching its armament automatically. The winners of the MX1179 contest were Hughes Aircraft, of Culver City, who were accordingly asked to undertake complete development of the system.

Seven years ago the U.S.A.F. had no guided air-to-air missile around which the company could develop its ideas, and Hughes accordingly determined the form which the weapon should take. In view of the anticipated high performance of the carrying vehicle it was decided to give the missile the highest possible speed, at the expense of range. This led to the concept of a very small missile, powered by a solid-propellant motor with a burning time of only 1½ seconds. General Electric had been developing such a missile under the project-name of Dragonfly, and Hughes revived this abandoned programme and used it as a basis for a complete air-launched missile system under the fighter-type designation of XF-98 Falcon. As described in our issue of December 7 last, Falcon is now widely used in the U.S. Air Force as the GAR-1 (guided air rocket). It weighs just over 100 lb, has a 6,000 lb-thrust motor and is a beam-rider with terminal homing. Later models, now in production at the Hughes missile plant at Tucson, have infra-red homing.

When, in 1951, Hughes were confidently able to predict the characteristics of the final Falcon missile and its associated MG-10 fire-control equipment, the Air Force asked airframe companies to submit their ideas for a machine to carry them. Each firm started off by attending a Hughes symposium on the weapons aspect of the system. Convair won the competition with their delta-wing project, and detailed design was initiated as the Convair Model 8 (U.S.A.F., XF-102). As far as possible, the new machine was a direct scale-up of the 7002, to a linear ratio of about 1.22. The original design gross weight was about 30,000 lb, and the engine chosen was the Pratt and Whitney J57 two-spool unit, which was then running in experimental form.

Long before the fire-control and missile were anything like ready, Convair had finished the design of the Model 8. Although a direct scale of the Model 7002, its lateral intakes gave it a different appearance, and in detail it was a largely redesigned aeroplane. In view of the U.S.A.F. requirement for well over a thousand F-102s (i.e., this was the potential market), Convair decided to employ constructional methods suited to a long run at a high rate of production.

A particularly fundamental outcome of this doctrine was the adoption of an exceptional proportion of forged parts. The U.S.A.F. heavy-press programme (which then stood at $389m) was relied upon to deliver complete fuselage frames, wing spars and longitudinal members—a total of eight types of part—all designed to be pressed from single large forgings. Such a decision reduced the weight of each aircraft by over 100 lb, and saved 273 components and 3,200 rivets. Alcoa and Wyman-Gordon were made chief "heavy-pressers." Another fundamental factor was that the Convair intercepter was the first aircraft to be planned for production under the Cook/Craigie plan.

Generals Orval R. Cook and Laurence Craigie were the joint authors of a scheme suggesting an idealized production cycle for U.S.A.F. weapon systems. From the drawing board, production tooling would be installed with a capacity for production at the maximum rate envisaged, and it would then be used for the manufacture of a progressively accelerating flow of aircraft. The first machine, for example, might be followed by the second one month later and by the third a week after that; after three months the delivery rate might be six per month, perhaps rising to 60 per month a year later. Such a scheme was intended to permit intensive test flying with an increasing number of aircraft to uncover all the major "bugs" before the production flow accelerated to the final torrent. By 1952 Cook/Craigie ideas were guiding many Air Force programmes, but the 102 was tied to the concept from the beginning. Convair could not have foreseen how important this fact would become.

By overworking some San Diego departments, the first YF-102 (serial number 52-7994) was ready for trials in the autumn of 1953. It was trucked to Edwards, and there flown by R. L. (Dick) Johnson, chief engineering test pilot, on October 24 of that year. Most unfortunately, it suffered engine-failure at take-off on November 2 and was damaged beyond repair in the subsequent emergency landing. It was not possible to continue flight trials until the second machine flew on January 11, 1954. Thereafter the test programme progressed normally until the flight envelope was pushed out horizontally towards the transonic regime. Over a period of a few ghastly days in the spring of 1954 it became clear that tunnel results had been optimistic, and that transonic drag of the YF-102 was greater than the available thrust. In other words, Convair's supersonic intercepter was subsonic.

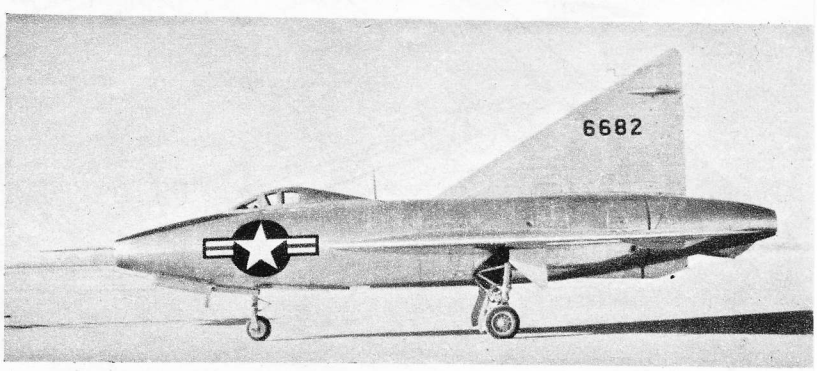
This put the whole programme in jeopardy. The Air Force had stipulated a supersonic Mach number in the original specification, and complete failure of so fundamental a nature was sufficient ground for cancellation of all the contracts placed. The YF-102 was already equipped with the biggest and most powerful flight-cleared engine in the western world. Somehow drag had to be reduced and by a wide margin.

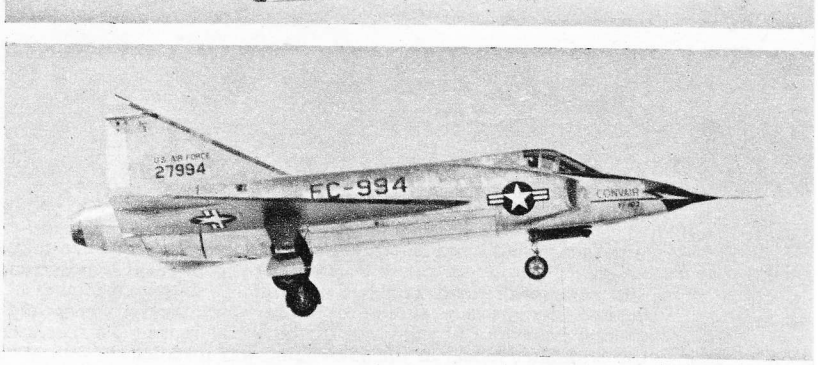
Fortuitously, salvation was immediately at hand. At the N.A.C.A. Langley laboratory a team under Richard Whitcomb evolved the area rule (*Flight*, September 30, 1955), a simple empirical law which, if properly applied to aircraft design, results in minimum transonic—and supersonic—drag. Convair's aeroplane did not conform to the rule, and the manner in which they made it do so, and the improvements which resulted, are now a classic in the annals of aircraft design.

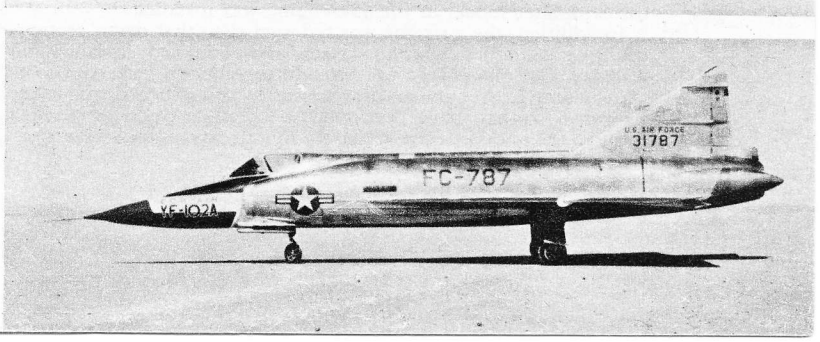
It was obvious from the start of the task that redesigning the airframe was going to be a major undertaking. Having several months thus occupied, the company decided to see in what other ways their intercepter could be improved.

The YF-102 was not really an inspired design. It was built like previous aircraft, large assemblies being erected to form a virtually complete airframe upon which several thousand man-hours then had to be expended on the installation and testing of sundry details, systems and equipment. Much of the interior was unduly inaccessible, and many of the most important maintenance or replacement tasks could not be undertaken without first removing the complete powerplant. Moreover, pilot view had been found to be inadequate, especially at extreme angles of attack. Convair pulled the whole design apart and, by re-engineering the aircraft in more intimate co-operation with the shop floor and the customer, turned the 102 into an excellent combat weapon and a production engineer's dream.

Superficial changes to reduce transonic drag involved major revision of the fuselage profile to give reduced cross-sectional area over the wing and the filling-in of the area diagram by the addition of huge bulged fillets flanking the jet-pipe and propelling nozzle. The wings were given partial conical camber (progressive increase in leading-edge camber from the root to near the tip, giving a marked negative-incidence entry over the outboard portions) to reduce drag at high altitudes and to improve behaviour at high angles of attack. The fuselage was greatly lengthened and the nose

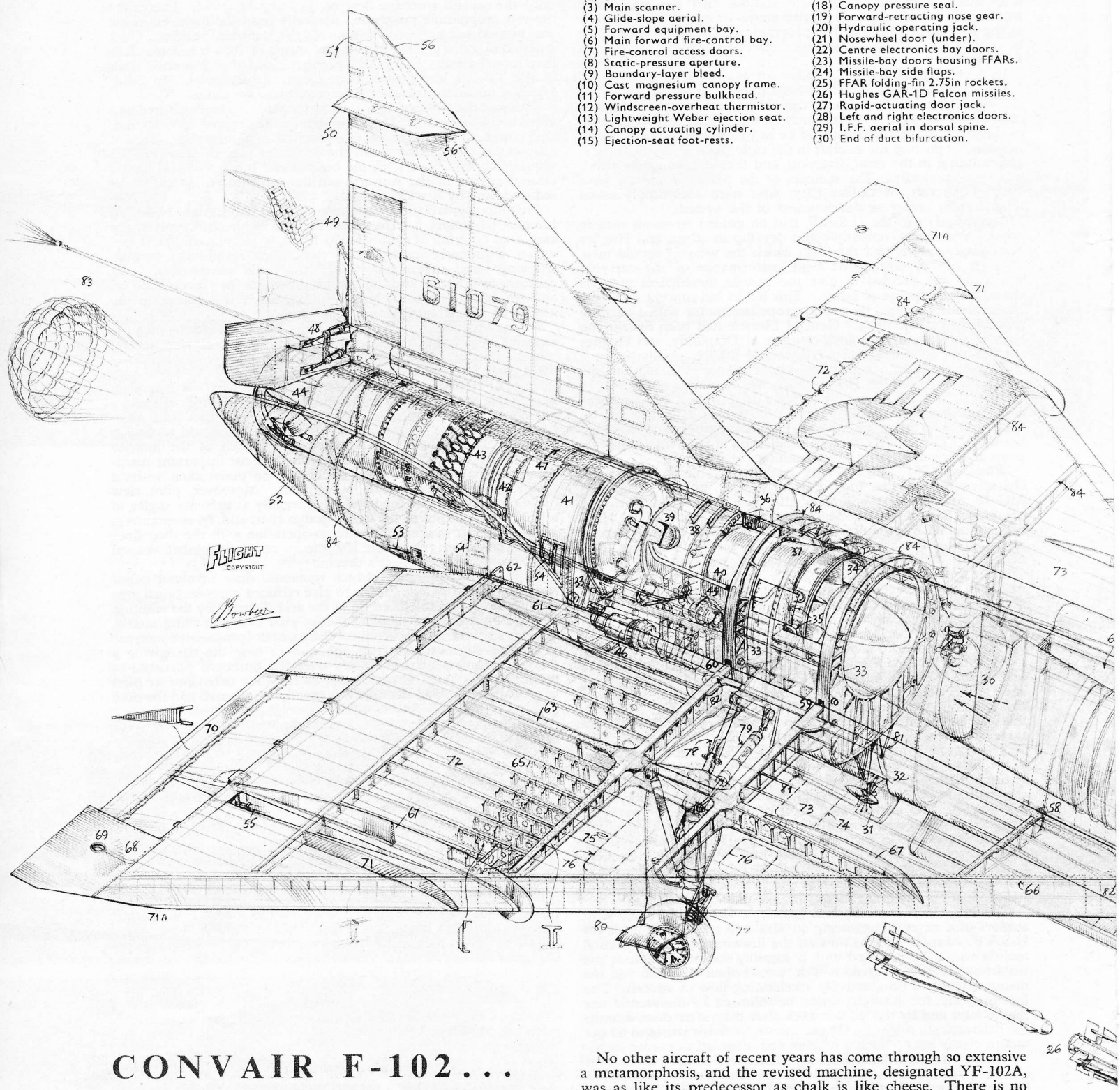






Top to bottom: The XF-92 Model 7002 (46-682) as originally built; the first YF-102 (52-7994); and the first area-ruled YF-102A (53-1787).

(1) Pitot boom.
(2) Dielectric nose-cap.
(3) Main scanner.
(4) Glide-slope aerial.
(5) Forward equipment bay.
(6) Main forward fire-control bay.
(7) Fire-control access doors.
(8) Static-pressure aperture.
(9) Boundary-layer bleed.
(10) Cast magnesium canopy frame.
(11) Forward pressure bulkhead.
(12) Windscreen-overheat thermistor.
(13) Lightweight Weber ejection seat.
(14) Canopy actuating cylinder.
(15) Ejection-seat foot-rests.
(16) Cockpit pressure relief valve.
(17) Cockpit discharge louvres.
(18) Canopy pressure seal.
(19) Forward-retracting nose gear.
(20) Hydraulic operating jack.
(21) Nosewheel door (under).
(22) Centre electronics bay doors.
(23) Missile-bay doors housing FFARs.
(24) Missile-bay side flaps.
(25) FFAR folding-fin 2.75in rockets.
(26) Hughes GAR-1D Falcon missiles.
(27) Rapid-actuating door jack.
(28) Left and right electronics doors.
(29) I.F.F. aerial in dorsal spine.
(30) End of duct bifurcation.



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was "sharpened" and lowered to reduce drag and improve pilot vision. The canopy was redesigned with a modified windscreen and a narrower hood with flat side-panels. Cut-back intakes of revised design were fitted, to improve pressure-recovery and general behaviour at extremes of the speed range. To increase thrust, a later model of the J57 engine was installed.

In addition, the airframe was redesigned so that major sections could be assembled, with all systems and equipment installed and tested, before the parts were brought together to make the complete aircraft. A number of accessories and other details were relocated, so that items previously inaccessible could be reached through the undercarriage wells, the missile bay, or *ad hoc* hatches.

No other aircraft of recent years has come through so extensive a metamorphosis, and the revised machine, designated YF-102A, was as like its predecessor as chalk is like cheese. There is no doubt that its emergence marked the turning-point in the 102's fortunes. But for the inability of the original aircraft to surmount the Mach hurdle, the production aeroplane would not have been so good; and, to this extent, that set-back was fortunate.

Redesigning took 117 working days, and the first YF-102A (serial 53-1787) flew at Lindbergh Field, San Diego, on December 20, 1954. The following day Dick Johnson went supersonic while climbing; he levelled off at 35,000ft and watched the needle rising still further beyond Mach 1.

Thanks to the Cook/Craigie plan only twelve aircraft had been built when the design was changed (the first "production" machine, 53-1781, flew in March 1954) and most of these aircraft were more or less brought up to F-102A standard. Convair were also

(31) Ram-air turbine and pump.
(32) Hydraulic reservoir and accumulator.
(33) Forged aluminium-alloy frames.
(34) Engine intake casing.
(35) Front engine mount and access.
(36) Saddle oil tank.
(37) Low-pressure compressor.
(38) High-pressure compressor.
(39) Blow-off valves and flush vents (2).
(40) Anti-icing air to intake.
(41) Can-annular combustion section.
(42) Turbine (1 h.-p. stage plus 2 l-p.).
(43) Afterburner fuel gallery.
(44) Nozzle actuator jacks (8).
(45) Packaged accessories section.
(46) Sundstrand-driven alternator.
(47) Dimpled titanium shroud.
(48) Speed brakes, duplicated actuation.
(49) Honeycomb-filled rudder.
(50) Fence aerial } wave-guide, parasitic, omni-range,
(51) Dielectric tip } I.F.F. and U.H.F. aerials.
(52) Area-rule blisters.
(53) Elevon streamline index.
(54) Inner-elevon actuator access.
(55) Outer-elevon actuator.
(56) Anti-erosion fin leading edge.
(57) Wing front steady.
(58) Bolted front wing pick-up.
(59) Attachment of 8ft forged spar.
(60) Attachment of 10ft forged spar.
(61) Attachment of 13ft 9in forged spar.
(62) Titanium elevon spar root.
(63) Heavy chordwise member.
(64) Heavy root rib.
(65) Ribs: angle flanges, sheet webs.
(66) Machined leading-edge member.
(67) Honeycomb-stabilized fences.
(68) Honeycomb-filled wing tips.
(69) Up-and-down navigation light.
(70) Honeycomb-filled trailing edge.
(71) Conical camber out to point 71A.
(72) No. 1 fuel tank, machined skin.
(73) No. 2 tank, integrally sealed.
(74) Access to float and relief valves.
(75) Fuel-system vent.
(76) Fuel-system access panels.
(77) Menasco main undercarriage.
(78) Breaker strut.
(79) Hydraulic retraction jack.
(80) Door, actuated by leg.
(81) Wheel-well doors on fuselage.
(82) Slinging points.
(83) Braking parachute strop and canopy (not to scale).
(84) Main production breaks (stations 217, 300, 405, 443, 481 and 643).

faced with the task of altering much of the tooling to conform to the new configuration. Some of the early tooling had been farmed out to the sister factory at Fort Worth and elsewhere, but by 1953 the entire production responsibility for the 102 had been vested in Plant 2 at San Diego, a vast rectangular block erected in 1941 to make B-24s. Sold to a non-aeronautical firm after World War 2, it had been acquired by the Air Force in 1952 and turned over to Convair. The Air Force also supplied the bulk of the machine tools and much other equipment.

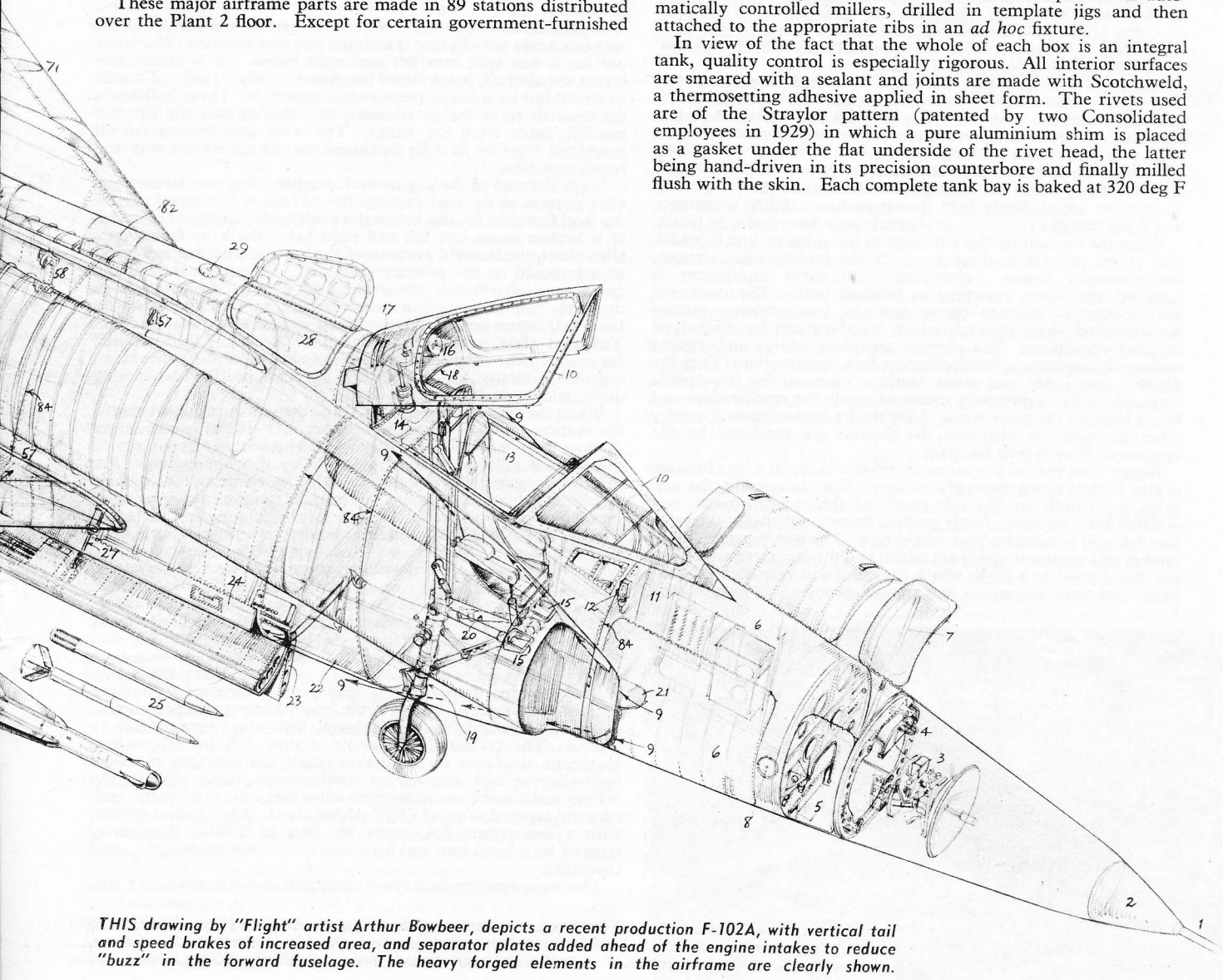
Convair moved into Plant 2 in earnest during 1953, and the empty acres were rapidly turned into a production floor as efficient as any in the world. The manager of the plant, Mr. A. P. Higgins (former chief tool engineer at Fort Worth), was admittedly fortunate in being able to plan well ahead, with a prospect of steady production of a very large number of aircraft. The redesigned airframe was broken down into sections—forward fuselage, centre fuselage, rear fuselage and wing, each sub-divided into left-hand and right-hand portions. Such sub-division eased jigging and handling problems, yet left portions large enough to allow the optimum concentration of manpower to be applied to each.

These major airframe parts are made in 89 stations distributed over the Plant 2 floor. Except for certain government-furnished or particularly costly items, all the components are made in batches of 150 and sent to line-stock bins at the appropriate stations. Subsequent manufacture of the airframe is worthy of description.

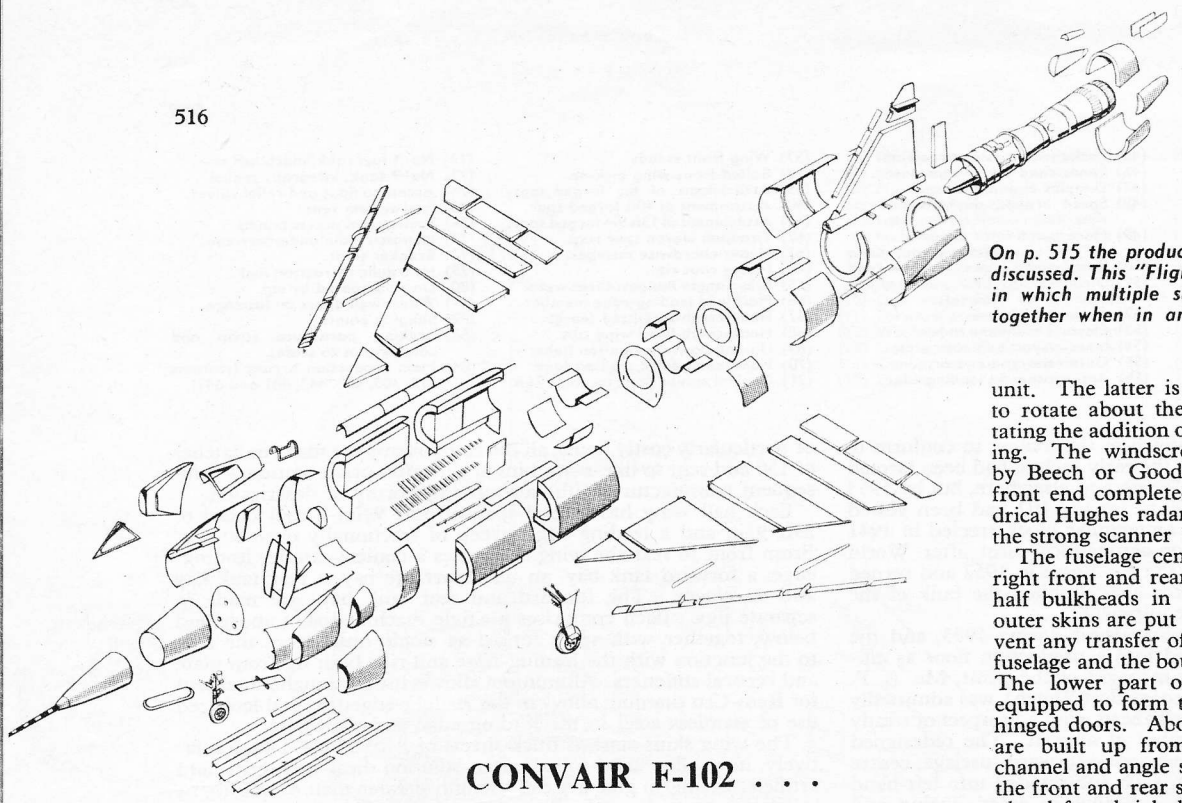
Each half wing has a semi-span of 15ft 9¾in, a root chord of 29ft 9¼in and a leading-edge sweep of fractionally over 60 deg. From front to rear the wing comprises a conical-camber leading-edge, a forward tank bay, an undercarriage bay, a rear tank bay and an elevon. The forward and rear tank bays are made in separate jigs. Each comprises a single machined skin above and below, together with spars forged as single units from the root to the junction with the leading-edge and ribs built up from plate and vertical stiffeners. Aluminium alloy is used throughout, except for Rem-Cru titanium alloys in the leading-edge ribs and localized use of stainless steel in the leading edge and elsewhere.

The wing skins start as thick sheets of Alcoa 2024-T86, a relatively new alloy cold-rolled after solution heat-treatment and artificial ageing to give a yield-strength greater than 67,000 lb/sq in at temperatures as high as 200 deg F. The sheets are continuous over each tank bay, those for the rear tank measuring no less than 96in by 250in. The sheets are sculptured in automatically controlled millers, drilled in template jigs and then attached to the appropriate ribs in an *ad hoc* fixture.

In view of the fact that the whole of each box is an integral tank, quality control is especially rigorous. All interior surfaces are smeared with a sealant and joints are made with Scotchweld, a thermosetting adhesive applied in sheet form. The rivets used are of the Straylor pattern (patented by two Consolidated employees in 1929) in which a pure aluminium shim is placed as a gasket under the flat underside of the rivet head, the latter being hand-driven in its precision counterbore and finally milled flush with the skin. Each complete tank bay is baked at 320 deg F



THIS drawing by "Flight" artist Arthur Bowbeer, depicts a recent production F-102A, with vertical tail and speed brakes of increased area, and separator plates added ahead of the engine intakes to reduce "buzz" in the forward fuselage. The heavy forged elements in the airframe are clearly shown.



On p. 515 the production breakdown of the F-102A is discussed. This "Flight" diagram clarifies the manner in which multiple sub-assemblies are finally joined together when in an advanced state of completion.

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to bond the Scotchweld, after which the access panels in the bottom skin are locked in place and the complete assembly pressure tested at 7½ lb/sq in. Certain wings are also pressure-tested with fuel cooled to about −70 deg C by liquid carbon dioxide. Except in completely destructive crashes (of which there have been very few) the F-102 wing has yet to suffer a leak.

Front and rear tank bays are joined in a large vertical tubular-steel jig in which port and starboard surfaces are mounted simultaneously, with the wing roots near the floor and the trailing edges vertical. Millers accurately machine the leading-edge of each front spar, while borers cut the undercarriage attachments, routers trim the periphery of the wheel well and a battery of precision borers simultaneously finish the multiple attachments at the wing roots. Tolerances are so finely held that interchangeability is assured, and wing changes are now a field operation taking under 24 hours.

From the vertical jig the wings go to the primary line in which they move through stations at which the leading-edge, elevons, undercarriage, fences, "plumbing" and other equipment is installed, the wings emerging as finished units. The cambered leading-edge is screwed on in sections, incorporating porous stainless-steel sheet through which bleed-air can be discharged in icing conditions. The elevons are plain tabless and gapless surfaces incorporating bonded honeycomb construction. They are divided into inner and outer sections operated by irreversible hydraulic jacks, respectively mounted inside the rear fuselage and faired beneath the outer wing. Like the leading-edges and sundry other parts of the airframe, the elevons are produced by the company's Fort Worth Division.

Bigger than that of any other single-seat aeroplane, the fuselage is also broken down into sub-sections. Chronologically, the first parts to be built are the side panels of the cockpit, based on a skeleton built up from closely pitched frames and stringers riveted together and bonded by Scotchweld tape. The heavy-gauge engine intakes and separator plates are added and the complete assemblies are then passed to a jig in which the front and rear cockpit bulkheads and floor are put in and the whole joined to form a rigid unit. The latter is then mounted in a fixture free to rotate about the longitudinal axis, thus facilitating the addition of all major controls and plumbing. The windscreen, a large assembly supplied by Beech or Goodyear, is then attached and the front end completed by offering-up the big cylindrical Hughes radar bay which extends forward to the strong scanner bulkhead at station 80.

The fuselage centre section is made in left and right front and rear quarters, all of which start as half bulkheads in separate jigs. The inner and outer skins are put on and the joints sealed to prevent any transfer of air between the interior of the fuselage and the boundary layer over the outer skin. The lower part of each half of this section is equipped to form the missile bay, with six piano-hinged doors. Above, the big ducts to the engine are built up from sheet stabilized by multiple channel and angle sections. When largely finished the front and rear sections are joined to form complete left and right halves, which are again united to form the finished centre fuselage. Movements of such portions of airframe are accomplished without cranes or external handling devices.

A parallel set of jigs holds the components of the rear fuselage, which is again sub-divided into front and rear sections. The front portion is not split into left and right halves but is continuous across the aircraft, being based on tremendously strong bulkheads squeezed out by a heavy press in one operation. These bulkheads are used to carry the powerplant, and also to bear the lift and bending loads from the wings. The wing attachments are all machined together in a jig to ensure correct agreement with the heavy root-ribs.

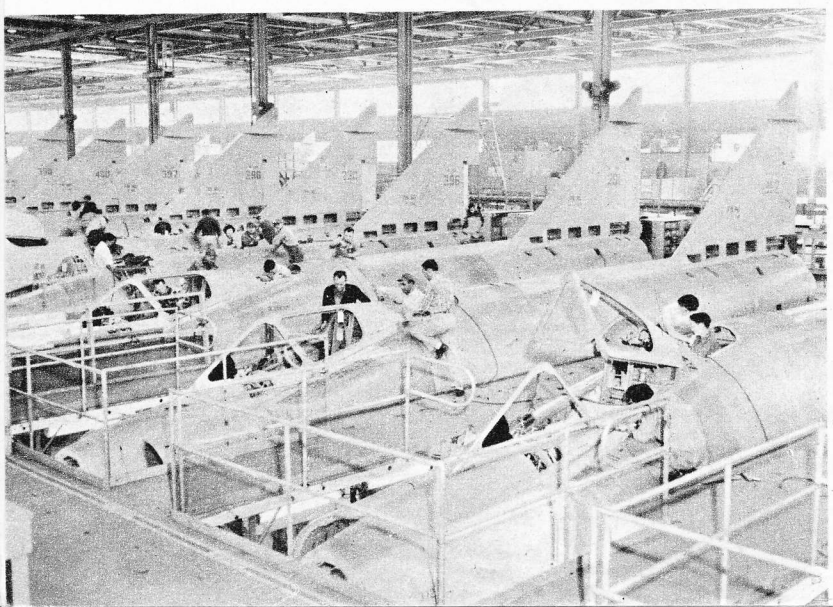
Since the rear of the engine and afterburner is cantilevered the after portion of the rear fuselage has to bear only a small part of the load from the fin and is therefore relatively lightly constructed. It is broken down into left and right halves built up from light-alloy sheet, the forward portions of the big area-rule fairings being superimposed on the primary structure. Inside this section, the engine and afterburner are shielded by a large shroud made of dimpled "waffle sheet" in commercially pure Mallory-Sharon titanium, seam-welded to machined rings of top-hat section. Titanium alloy, mostly Rem-Cru C-110M or C-130M, is used for many of the fuselage frames in the vicinity of the powerplant, together with spar fittings, hot skin sections, heating and venting ducts, and engine attachments.

When the forward and after parts of the rear fuselage are mated the vertical tail is also attached. Current F-102As have a larger fin than their predecessors. Rheem, who make the unit, redesigned the vertical tail to obviate the possibility of roll-coupling. Fin height was increased from 104 to 137in by reducing the leading-edge sweep to 52 deg; at the same time, the trailing edge, previously raked forward, was made vertical. The area was thus increased from 68 to 95 sq ft. The change reduces performance but is considered more reliable than additional stability augmentation.

The new fin has a rectangular-pattern skeleton terminating in an axial row of anchorages which locate on major fuselage frames. The extreme tip is a dielectric aerial, and aerials are also incorporated in the fence-like rudimentary tailplane which effectively increases the fin aspect ratio. At the rear end the fin root provides anchorages for the speed brakes, which have also been recently increased in area. Ahead of them is the drag-chute box.

Resin-bonded honeycomb is very extensively used to stabilize parts of the airframe. Many of the honeycomb structures are produced by Narmco, using hexagonal light-alloy cores made by Hexcel. The rudder, for example, a unit 4½ft by 2½ft with a maximum thickness of 3in, has a single channel spar of 0.04in light-alloy, a cast magnesium trailing-edge, hinge and control fittings machined from aluminium-alloy forgings, sheet-metal end-ribs and tapered skins of 75ST Alclad sheet. The interior is filled with a honeycomb ⅛in across the flats in 0.001in aluminium, tapered by a band-saw and hand-sanded to give slight compound curvature.

The wing-tips are even more ambitious, having compound cur-



Closely-spaced fuselages are eloquent of the high production rate which Plant 2 is maintaining on the big intercepter. Here, front, centre and rear sections have just left the joining stage.

vature and washout over their entire area of some 4½ft by 2½ft, the thickness tapering from 2½ to ½in. The core is a ¼in honeycomb in 0.002 aluminium, bordered by magnesium castings and incorporating a ½in light-alloy conduit for the navigation light. Generally similar construction is employed for the trailing-edges of the elevons (⅛in by 0.001in core with a 75ST channel spar and 0.02in 24ST6 skins), the wing fences (with a similar core and attached to the wing by T-section magnesium extrusions) and the nosewheel door with a core about 2in thick bordered by a drop-hammered S-section.

Major fuselage mating takes place in a simple jig in which the centre fuselage is rigidly located while the front and rear sections are brought into precise alignment by hand cranks and levers. The wings come up from their primary line on track-mounted dollies and, with optical tracking to maintain alignment, are jacked up on each side of the fuselage and the attachment bolts inserted. The complete job, including all the hydraulic, electric, fuel and pneumatic connections, takes three hours. The aircraft, not yet on its own wheels, moves down the final line for a long sequence of functional tests, during which the radome and pitot boom are installed and the powerplant put in.

The latter is a Pratt and Whitney J-57-P-35 rated at 10,900 lb dry thrust, 13,000 lb wet and 17,000 lb with its long afterburner (eight-segment nozzle) in operation. The powerplants are prepared for installation in rotating dollies, from which they are lifted to fuselage level and slid in along lateral tracks. Unlike those of most American fighters, the engine is installed with the rear fuselage *in situ*. The afterburner nozzle is then cowled with the final fuselage assembly, which incorporates the rear portions of the area-rule fairings. This part is made by Rheem in titanium.

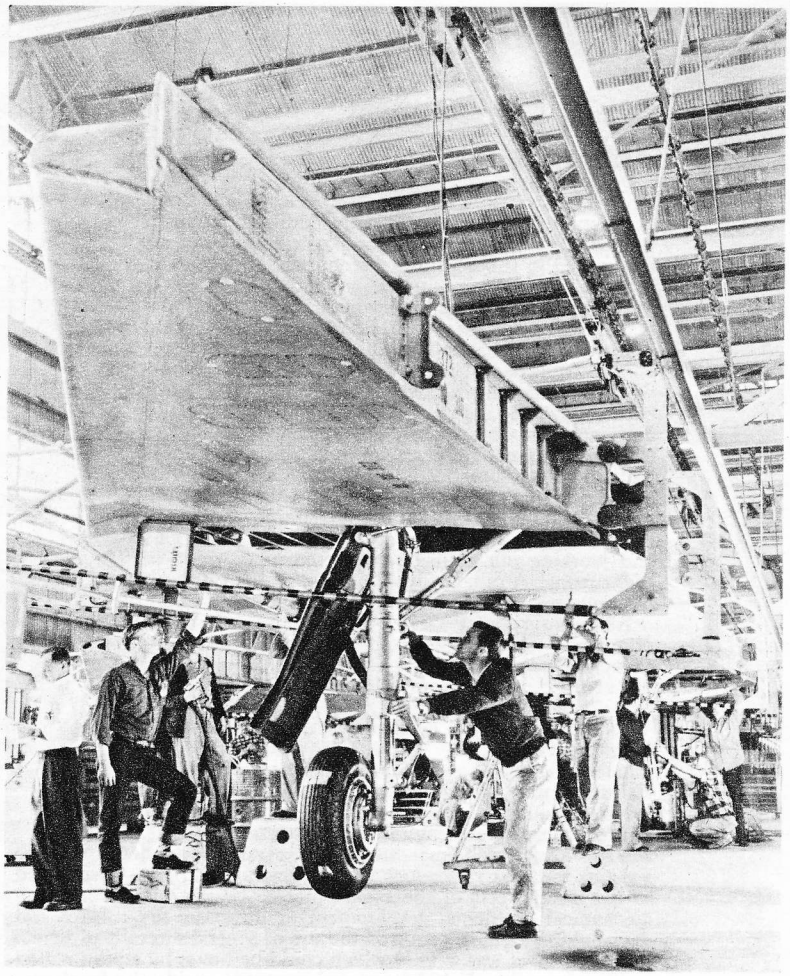
In keeping with normal U.S.A.F. practice with combat aircraft the F-102 has an ejection seat operated by lateral hand-grips. Weber, who make the seat, state that the complete ejection cycle can be accomplished in two seconds, even under supersonic conditions. When the pilot raises the seat hand-grip the cockpit is depressurized and the canopy unlocked and jettisoned. A further 15-deg movement raises the pilot's forearm guards and locks the inertia reel of his shoulder harness. The seat is then fired by squeezing the hand-grip trigger. (Incidentally, Convair are co-ordinaters of the standardized escape system for future U.S.A.F. fighters and have developed a rocket-boosted seat with a very high trajectory.)

In normal cruising flight the cockpit is pressurized to 7.2 lb/sq in, although for flights above 50,000ft the MC-1 partial-pressure suit has to be worn. Air-conditioning has been handled by the Stratos Division of Fairchild. The F-102 is one of the first aircraft to have a canopy glazed with stretched plastic. Earlier as-cast acrylic canopies could be shattered by impact or gun-fire, and in the 102 subsequent pressure inside the cockpit dropped below zero (gauge pressure) in less than 0.02 sec. When the stretched material, supplied for the 102 by Swedlow, is subjected to 0.30-cal gun-fire a neat hole results and the cockpit pressure falls off comparatively gradually, taking two seconds to drop to 5.9 lb/sq in. Windscreen panels, supplied by Pittsburgh Plate Glass, comprise (from the inside) ½in tempered glass, ⅛in vinyl and $\frac{3}{16}$in tempered glass with Nesa electric conducting film on the inner face. The panels are demisted by hot air and are protected against overheating by a spring-loaded probe leading to a Fenwal thermistor.

As already noted, the elevons and rudder are hydraulically actuated, their control valves being moved by Hyco-Span cable to minimize thermal expansion inaccuracies. Retraction of the Menasco undercarriage and operation of the missile-bay doors and speed brakes are also hydraulic. Both primary and secondary systems operate at 3,000 lb/sq in and are energized by two Vickers variable-displacement pumps mounted on the wheelcase under the engine.

Another Vickers pump, of the constant-displacement type, is mounted on the same shaft as the ram-air turbine, which in emergency is extended from a bay in the fuselage. It drives a 3,000 lb/sq in closed circuit energizing a constant-speed hydraulic motor driving the stand-by alternator (which can also be driven by the secondary hydraulic system). A flow-sensitive pressure regulator limits the ram-air output pressure to maintain satisfactory flow down to minimum flying speed. The capacity of the ram-air unit is considerable, since it has to be capable of supplying the heavy electrical loads needed by the fire-control system. Moreover, the latter needs current with closely controlled frequency and the ram-air delivery is accordingly regulated to within 0.01 per cent r.p.m.

Normal electrical power is drawn from a big 400 c/s alternator driven mechanically *via* a Sundstrand variable-ratio drive. The latter maintains frequency-control to the same accuracy as that quoted above. The alternator is a blast-cooled Jack and Heintz unit. This company also supply the magnetic-amplifier voltage regulator and the control panel, which uses a new gas-discharge over-voltage detector tube insensitive to acceleration. The whole system was the first to go into production meeting military class C (120 deg C) requirements.



A view of the wing primary line in Plant 2 at San Diego. The F-102 wings are virtually finished while suspended from overhead tracks. The pronounced conical camber of the leading edge is clearly visible.

In spite of the great size of the fuselage most of the fuel is contained within the wings. There is, however, space for several hundred gallons to the rear of the missile and wheel bays. The whole rear end of the fuselage is occupied by the bulky powerplant, which is closely cowled within a stainless-steel and titanium bay protected by Edison continuous-resetting fire detectors (for which equipment the 102 was the first production application).

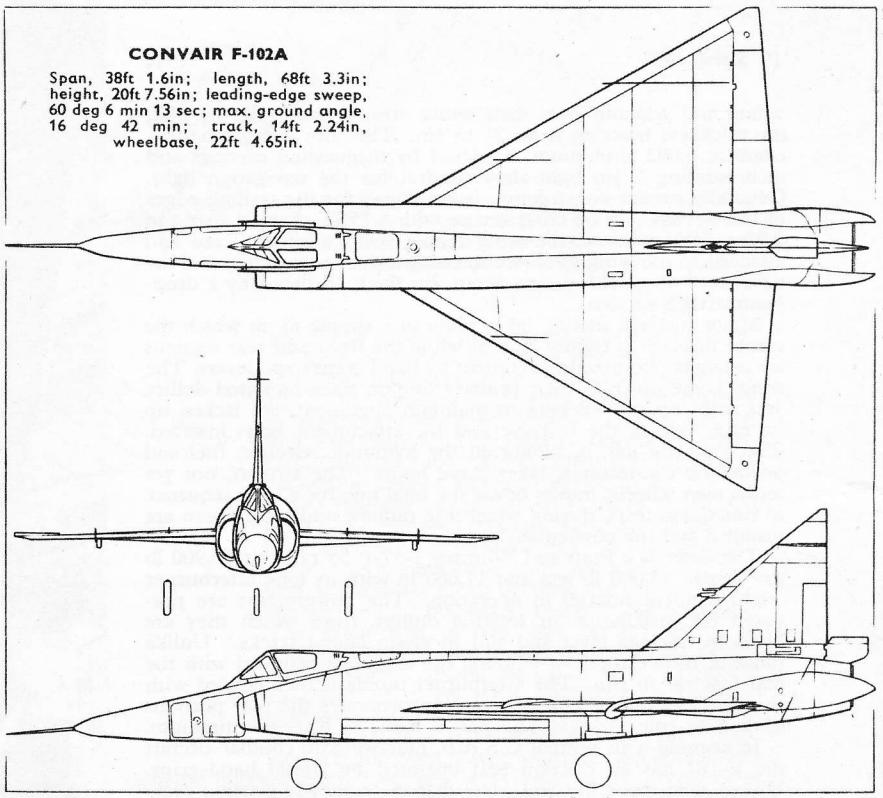
More important than any other part of the aircraft is the Hughes fire-control and missile system. During the five years that Convair and Hughes have taken to perfect this installation, monthly meetings have been held to keep both manufacturers completely up to date on all design changes. In the initial period changes in equipment bulk were virtually inadmissible; and, since the fire-control is largely mounted in the nose, even small variations in the weight produced large changes in aircraft trim and optimum control design.

In its final form the MG-10 fire-control weighs 1,700 lb, occupies 28 cu ft and is installed as about 100 quickly replaced plug-in packages. So closely does it fit inside the airframe that great care was needed to ensure that the shock-mounted components could not strike parts of the aircraft during combat flying. At the front is the powerful microwave scanner beneath the large Zenith-made radome. The forward electronics bay, housing about half the total load, can be reached through four side-doors which extend a total of about 300 deg round the periphery of the bay. This is no mean structural achievement, particularly since aero-elastic distortion could impair electronic accuracy. Access to the centre bay is gained *via* a hatch beneath the cockpit and the rear electronics bay is reached through large doors just ahead of the main-wheel bay.

Basic data, including pitot information from the nose boom, is centralized by the Servomechanisms master air data computer, and used to control flight instruments and the MG-10 system. Minneapolis-Honeywell developed the gyro system, sensitive to movements about the three axes. Three JR rate gyros are used, each with a threshold of 0.01 deg/sec, built up with Barber-Colman monitoring micro-positioners (roll and pitch synchronizing and heading-engage networks) to form a pilot-assist and yaw-damper system. This actuates the elevons and rudder to counteract random oscillation. It is worth noting that Hughes had to build a simulator to duplicate the stability of the aircraft before the fire-control circuits could be designed.

Armament of the F-102 comprises six GAR-1D Falcons mounted on short rails which extend from the three missile bays

CONVAIR F-102 . . .


CONVAIR F-102A
Span, 38ft 1.6in; length, 68ft 3.3in; height, 20ft 7.56in; leading-edge sweep, 60 deg 6 min 13 sec; max. ground angle, 16 deg 42 min; track, 14ft 2.24in, wheelbase, 22ft 4.65in.

when the doors are opened. Preparation and firing are conducted electrically. In addition, a small number of 2.75in spin-stabilized folding-fin rockets are carried in tubes within the doors themselves and used as secondary armament.

In an interception, the scanner picks up its target at a range of many miles and then locks-on and follows it automatically. In this regime the fire-control feeds back directly into the hydraulic circuits which actuate the rudder and elevons. The latter surfaces had to be most carefully designed, since extremely small variations in their characteristics have a profound influence on the ability of the aircraft to run automatically towards its target. Actually the flight need not be "towards" the target in a curve of pursuit, since the MG-10 incorporates a computer capable of predicting future air situations and working out collision-course or other types of flight path. A radar scope, with which the pilot can monitor the interception, is mounted in the cockpit.

At the appropriate range—perhaps five miles—the armament salvo pre-selected by the pilot is automatically prepared for firing. Then, at precisely the right instant, the missile bay doors flick open and the weapons are fired.

Rapid-acting jacks open and shut the doors in a fraction of a second. Nevertheless much development was needed to ensure that the fierce blast of a Falcon motor would not create havoc inside the missile bay, nor have an adverse effect on the operation of the aircraft engine or fire-control systems. Many thorny problems—such as a persistent tendency for the Falcons to break range-lock at the moment of firing—were traced to the blast effects of the rocket motor. Quite apart from such mechanical problems, development of the basic fire-control and data-linking systems required the use of several aircraft, of which the most novel was a T-29 which could be flown by a pilot seated inside a complete F-102 front-end mounted inside the fuselage.

From Plant 2 completed aircraft, wearing an undercoat of paint (they are the only fighters in the U.S. Air Force to be painted) are taken to the fly-away base near the old B-36 gun butts at Lindbergh Field. Convair spent $340,000 on this facility, in which preliminary field operational cycles are conducted. A total of 15 run-up stations is provided, together with five tie-down points and full underground services. In fine weather finished aircraft then leave San Diego in pairs, so that each can provide surveillance and back-up communications for the other. Convair pilots ferry the aircraft 140 air miles north, to the company base at Palmdale in Antelope Valley. Since 1954 Convair have spent $10m here, and the facility can now handle 25 aircraft at once during final field operations and transfer of the aircraft to the Air Force. While at Palmdale the machines are given their coat of glossy grey paint (overall, except for a black nose and non-reflecting green above the intakes and ahead of the canopy).

Convair have now received five production contracts for F-102As, representing a total business of several hundred million dollars. The first true production aeroplane was formally accepted late last June by Captain (now Major) Don Butterfield, assistant Air Force plant representative and acceptance pilot on the 102. During last summer, aircraft were supplied to the 327th Fighter/Intercepter Sqn. of Air Defense Command at George A.F.B., Cal. The Sqn. Commander, Lt-Col. Charles E. Rigney, said that his new equipment was "the easiest plane to fly I've ever been in," and he soon demonstrated his mastery of the type by flying from his base to Oklahoma City, 1,120 miles in 82 minutes from brakes-off to passing the tower. This average speed of 819.5 m.p.h. was achieved with a non-afterburner climb and a cruise from 40,000 to 43,000ft. (His unit has suggested that the 102 be named Lancer, a proposal which is now being considered in Washington.)

By August, the 11th F/I Sqn. of the 343rd Fighter Group at Duluth, Minn., had been equipped, and this was then followed by the 4750th Air Defense Sqn. at Vincent A.F.B., Ariz.; 323rd F/I Sqn. at Truax A.F.B., Madison, Wis.; 31st F/I Sqn., Wurtsmith A.F.B., Wis.; 317th F/I Sqn., McChord A.F.B., Wash.; 2nd F/I, Suffolk County A.F.B., N.Y.; and a squadron based at Geiger Field, Spokane, Wash. Many other squadrons have been equipped with the aircraft during the past few weeks. Representatives of communities living near F-102 bases are given a free tour of Air Defense Command H.Q. at Colorado Springs and a two-day instructional course at San Diego, to enable them to appreciate that their noisy neighbour is a good thing.

Engineering flight-development for the Air Force is now centred at Edwards, armament at Holloman, electronics at Patrick and maintenance and supply at Kelly. Squadrons have already logged many thousands of hours during conversion and intensive training. As the 102 can operate at 54,000ft (higher than previous American fighters) B-57 Canberras are often employed as lock-on targets or as carriers for parachuted drones for live attack by Falcons. Exercises have indicated that the 102 is the only U.S.A.F. fighter able to "splash" a B-52 operating at top altitude. For the record, a typical time from "standing beside aircraft" to "wheels off" is 1 min 55 sec, and the landing roll can be held to 3,650ft even on icy runways.

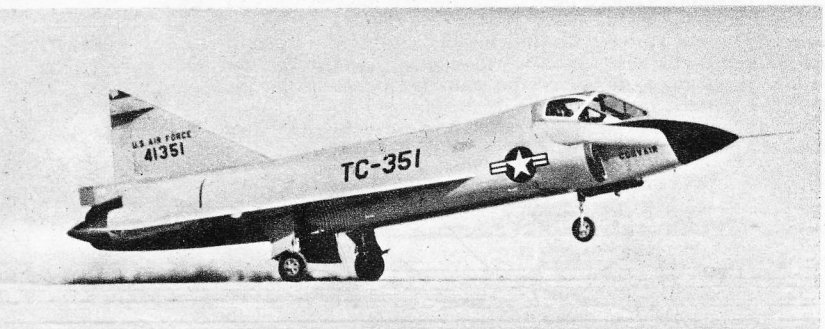
A total of 52 aircraft was engaged in initial flight development, and Convair's Fort Worth division are bringing these up to operational standard. At San Diego production is nearing its peak rate, with about 500 aircraft so far delivered. Many of the 15,000 extra employees which the "SD" division took on last year were absorbed by Plant 2's increased output. Current 102A contracts expire in July 1958.

In July 1955 Fort Worth delivered the first set of parts for the TF-102, a combat-proficiency trainer and tactical intercepter seating a pupil to port and an instructor to starboard in a dual-control cockpit. Compared with the single-seat 102 it has equal weapons ability but lower performance, and is shorter (63ft 4½in). The Texas factory ships complete TF front ends to San Diego for mating with standard wings and rear fuselages. TF aircraft were included in the 2nd, 3rd and 4th contracts for the 102.

During 1955 San Diego went ahead on a 102 development, able to fly at greater speed and altitude (to give it mastery over the Russian "Bison") and equipped with a new fire-control and weapon. Originally designated F-102B, this mighty machine has now emerged as the F-106A.

Compared with the 102A it has a bigger engine—the Pratt and Whitney J75, with afterburner—a revised structure with 18 heavy-press forgings, longer fuselage and broader, square-tipped wings and vertical tail, cut-back intakes at the wing roots and the most advanced fire-control yet developed, matched to a primary armament of two MB-1 (Ding Dong) nuclear air-to-air missiles. The first contract, placed in May last year, was for $83m. This was later brought up to $146m to include more aircraft, and a second $70.2m purchase was made in January.

Dick Johnson flew the first 106A at Edwards on Boxing Day. A number of the new fighters have now flown and it is reported that the design performance of Mach 2 and over 65,000ft has already been achieved. San Diego are also building the tandem-seat 106B (for which a $47m order was announced on April 11) and an advanced canard derivative, designated 106C, intended to reach Mach numbers of about 2.5. The indications are that Plant 2 will be making manned fighters for a long while yet.



The shorter, fatter nose of the TF-102 two-seater can be seen in this desert-landing photograph. The first TF-102 flew in November 1955.